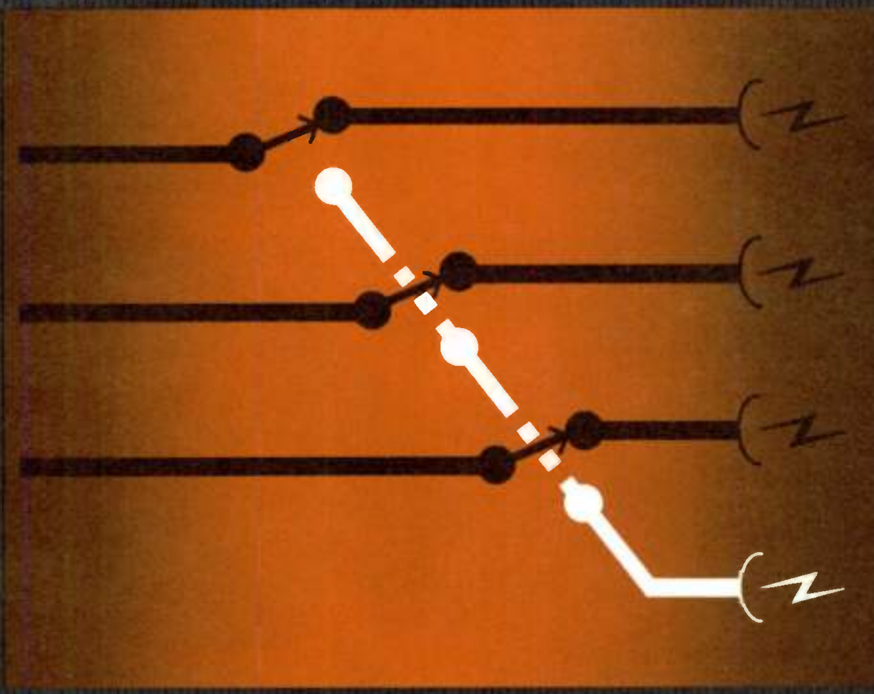
GTE LENKURT

DEMODULATOR

JUNE 1972

Multiline Protection Switching



A multiline switching system provides protection for microwave transmission paths. It is not only an economical method of protection, but is also a means of conserving bandwidth in crowded microwave bands.

Protection of Microwave communications channels is necessary in the event a working channel experiences an outage due to equipment malfunction, high noise, or severe fading. Frequency and space diversity and multiline switching are the most commonly used methods of microwave system protection. Both frequency and space diversity have the expensive disadvantage of requiring duplication of equipment (transmitters, receivers, and antennas) to protect a single radio channel. In addition, the extra frequency spectrum necessary for frequency diversity may not be available in many areas.

Multiline Switching

The concept of multiline switching is to allow one or two microwave radio channels to protect several radio channels. Multiline switching systems, such as GTE Lenkurt's 757C, utilize one or two radio channels to protect up to six working microwave radio channels. Such a system is effective on any high density radio route.

A typical section of a microwave radio route which uses multiline switching consists of about one to ten hops, with six hops as the average. This six-hop distance corresponds to approximately 150-180 miles, depending on the terrain and the operating frequency of the system. Greater distances are obtainable by installing additional switching systems in tandem. Thus, a microwave radio route of from a few hundred to several thousand miles may be divided into a specified number of switching sections, each containing the necessary hops to span the required distance with the greatest reliability.

The greatest advantages of a multiline switching system are economy in capital and efficient use of available frequency spectrum. Protection for six radio channels requires only one or two additional radio channels. An additional economic factor is in the flexibility of the system. A user of telecommunications equipment, for example, whose present requirements call for only one microwave radio channel, may install a multiline switching system. Initially, this will give him a one-for-one protection system. As his requirements for radio channels increase, the user can easily expand his facility and still retain adequate channel protection. This type of expansion allows the user to go from one-for-one

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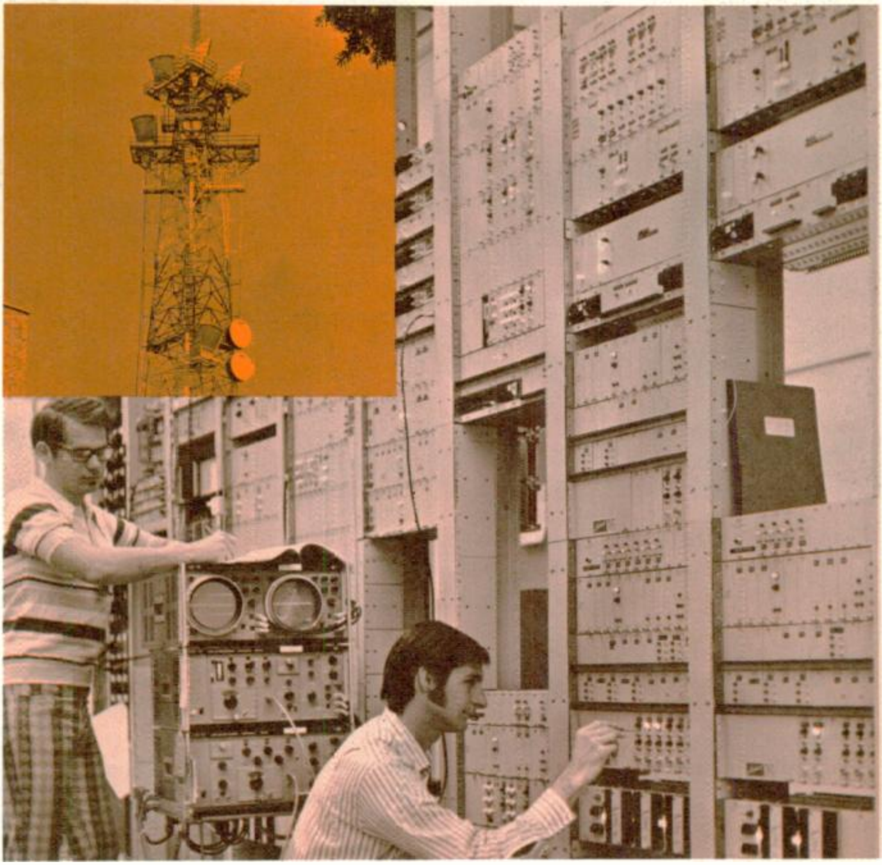

Figure 1. Switching centers, such as General Telephone's Clearwater, Florida office, may utilize a variety of baseband, IF, and modem multiline switches.

protection to two-for-six protection (two protection channels for six working channels).

Multiline Applications

A typical high density radio route contains several microwave radio channels. Each radio channel may in turn carry hundreds of information channels consisting of voice, data, or video and program channels. At present, as many as 1800 two-way FDM (frequency division multiplex) channels may be transmitted on a single radio channel. An outage on one such radio channel for a prolonged period would have wide-ranging consequences affecting a great number of customers. Multiline switching provides economical and efficient protection for such a system.

A multiline switching system is not restricted by any particular type of radio transmission equipment. It can be made applicable to relatively short routes which use baseband remodulating microwave radio, or long-haul IF interconnected heterodyne radio (see Figure 1).

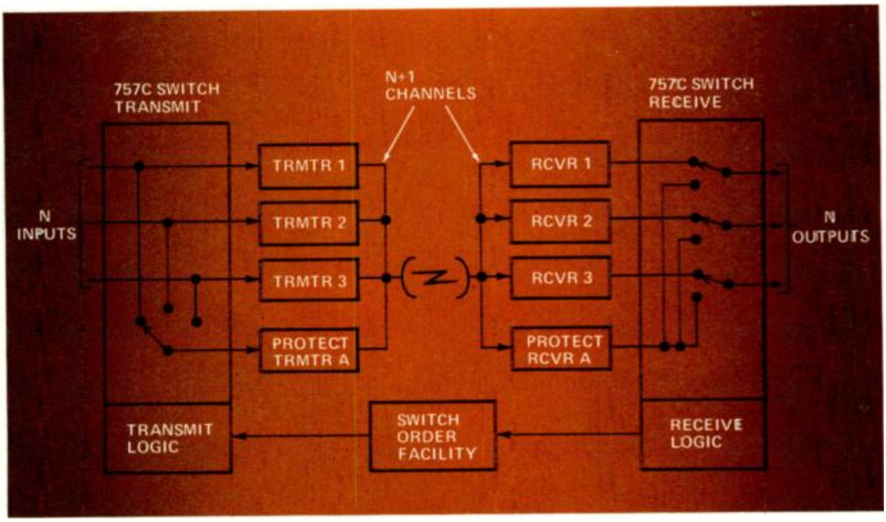

Figure 2. In a 1-for-3 protection system, one channel protects three working radio channels. Here, channel A protects channels 1, 2, and 3.

High density multiline switching is also used with coaxial cable systems, and although the switching philosophy is the same as for radio, signal loss considerations along the line are different. Only microwave radio considerations will be taken into account in this discussion.

Function of A Multiline Switch

The general configuration for a one-for-three multiline protection system going in one direction is shown in Figure 2. The mirror image of this system would appear for transmission in the opposite direction.

The basic operation of a multiline switching system is to transfer information from a failed circuit to a protection circuit, thereby bypassing the fault. There are various methods of doing this, but the basic philosophy is the same for most systems. On a given multiline-switching transmission path such as shown in Figure 2, there is a terminal of equipment which has N + 1 outputs on the transmitting end; N being the number of working channels in a system. On the transmit side of the switch, the common connection goes to the protection channel. Each of the poles on that switch, bridge the working radio channels. At the receive end, each working path has a two position switch. It is important that the switches on both the transmit and receive ends remain in constant synchronization. This synchronization is controlled by the logic contained in each end of the multiline switching section.

Types of Multiline Switches

There are two types of multiline switches – baseband and IF – each corresponding to the type of radio transmission used in a particular microwave system. Basically, the only significant difference between baseband and IF (intermediate frequency) systems is in the transmission-path equipment.

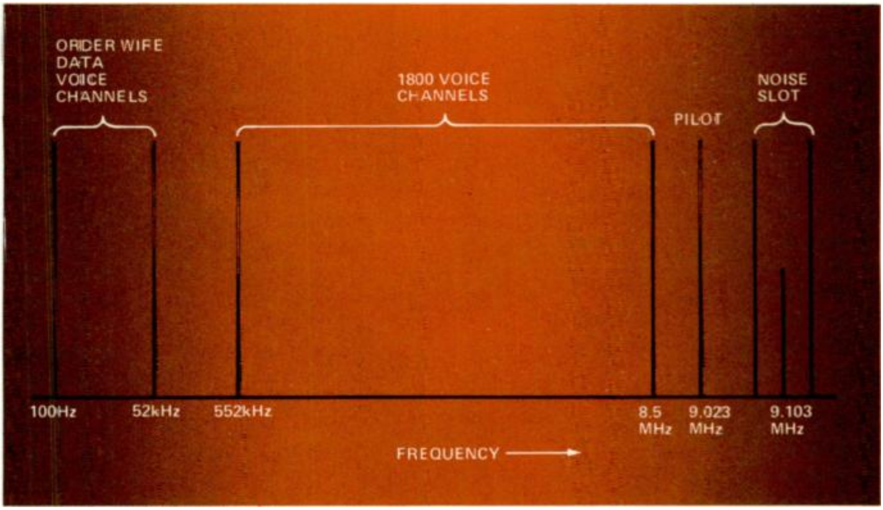

Figure 3. Example of frequency distribution in a microwave radio channel with an 1800 voice-channel capacity.

For a switching system to operate, it is necessary to have a way of determining when a transmission path has failed. This is done in the GTE Lenkurt 757C by monitoring noise and continuity. In baseband and some IF systems, each radio channel contains a fixed-frequency continuity pilot and a noise slot which are continuously monitored by the switching system. Both the pilot and noise slot are generally above the occupied baseband spectrum as shown in Figure 3. In IF systems which do not utilize a continuity pilot, a fixed noise slot and the intermediate frequency power at 70 MHz are monitored by the switching system. If a power-level change occurs at 70 MHz, or if increased noise appears in the noise slot, the switching system will initiate a transfer.

Switching Thresholds

The noise threshold of a microwave radio system is that point at which noise becomes great enough to render a channel useless for information transmission. In a multiline switching system, the "switching threshold" is not necessarily the same as the noise threshold of the radio equipment. The switching threshold – the point at which a particular switching system is designed to initiate a switching sequence – may be a few dB different than the noise threshold of the radio equipment, depending on the requirements of the system. These requirements will vary with the nature of the information being transmitted. When a switching threshold is surpassed, the system will initiate a switch to the protection channel.

Excessive noise in a microwave system may be caused by equipment failure, atmospheric changes which cause transmission-path fading, or adverse weather conditions such as heavy rainfall or fog. These conditions are detected by the multiline switching system by monitoring the noise slot. A degeneration of the pilot level may

TYPE OF TRAFFIC	MAXIMUM TOLERABLE INTERRUPT TIME	EFFECT IF TOLERANCE IS EXCEEDED
VIDEO	< 100 MICROSECONDS	LOSS OF SYNCHRONIZATION ROLLING
TELEGRAPH (50 BAUD)	< 1 MILLISECOND	ERROR
DATA	< 10 MICROSECONDS	ERROR
MESSAGE CIRCUITS	< 100 MILLISECONDS	SEIZURE OF CENTRAL OFFICE SWITCHING EQUIPMENT

Figure 4. The effect of an outage depends on the type of information being transmitted.

be caused by circuit interruption due to man-made error, a component failure which will not result in excessive noise but only in a total quieting of the transmission path, or a gradual deterioration of the circuit due to a long-term component failure. The occurence of any one or all of these conditions is sufficient to initiate a transfer sequence to the protection channel.

Multiline Switch Operation

In describing logic operations, it is often convenient to use anthropomorphic terms. For example, in achieving synchronization between the transmit and receive sections of a multiline switching system, the transmit and receive logic of the system must be able to "talk" to each other. The transmit logic must function under the control of the receive logic so that synchronization may exist between both ends.

When the pilot or noise detectors recognize a failed channel, the receive logic is notified. The receive logic initiates the switching sequence, and via the switch order facility, notifies the transmit logic to bridge the traffic of the failed channel to the protection channel. The switch order facility carries information from the receive logic to the transmit logic, either by transmitting the command information of the receive logic to the transmit logic using an unused portion of frequency spectrum of one or two radio channels going in the opposite direction, or by external order wire radio or cable facilities. The transmit logic must then determine the availability of the protection channel. Is the protection channel available? Is it already being used to protect another channel? These are some of the decisions which the transmit logic must make before initiating a bridge to the protection channel. If the channel is already in protection mode, or if it is not functioning properly, it will not react to the switch order request. If the protection channel is available, the transmit logic then bridges the traffic of the failed channel to the protection channel which then relays the information to the receive end.

The receive end detects that the information of the failed channel is now on the protection channel. This will tell the receive logic that the transmit end has bridged the correct channel to the protection channel and that the protection channel is operating properly. The receive logic then completes the switching sequence by transferring the information of the failed channel around the fault and on to its original route.

The time required for the complete switching sequence is no more than 30 milliseconds, depending in part on such things as the number of repeaters between terminals and type of switch order facility used. The *actual* interrupt time of the circuit is approximately two microseconds since the switching sequence begins before a channel has completely failed. The switching sequence begins at a point predetermined by the switching threshold of the system.

Effects of Outages

The effects of an outage on the various types of information is unique to the information itself. For example, message circuits may sustain much longer outages or "hits," without errors, than can a data circuit. The effects of hits on various types of information carried by a radio channel which is protected by multiline switching is shown in Figure 4.

Other Uses

The protection channel of a multiline switching system may serve as a restoration circuit in times of emergency to re-establish communication service when disruption of radio channels not within its own system has occurred. Also, the user may use the protection channel to transmit low-priority information which could be immediately dropped should protection be necessary for one of the main working channels of the system. In this way, a user may get the maximum benefit from his multiline switching system.

Priority Channel

Multiline switching systems may offer a priority-channel option. A priority channel is that working channel which is regarded by the user as the most important. Should this channel fail, the protection channel will immediately take its place, even if it is protecting another channel at that time.

Many telephone companies which use multiline switching do not utilize the priority option because they consider any working channel just as important as any other working channel. In this case, no channel takes precedence.

A multiline switching system is an economical way of protecting the channels in a microwave or coaxial system. It is not the answer to every system-protection problem, but it is certainly an efficient and reliable method of providing protection for high density systems.

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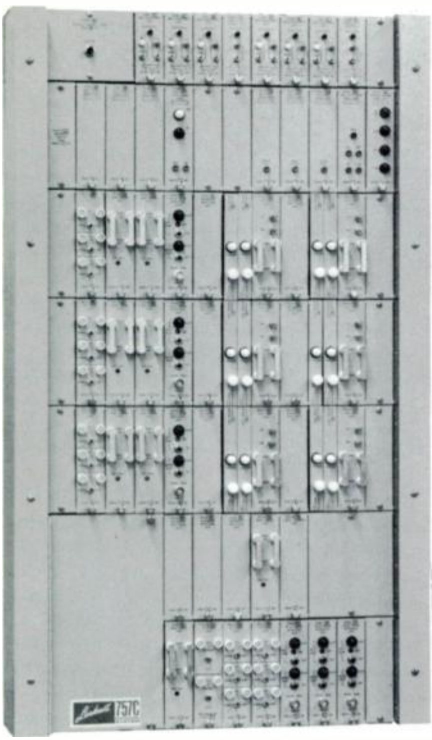

An entire family of GTE Lenkurt 757C multiline switches is now available.

- BASEBAND
- IF
- MODEM

For additional information, write GTE Lenkurt, Department C134.

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TRANSMISSION SYSTEMS

The GTE Lenkurt Demodulator is circulated monthly to technicians, engineers and managers employed by companies or government agencies who use and operate communications systems, and to educational institutions.

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DEMODULATOR

MAY 1972

microwave applications

Each microwave communications network is designed to fit its specific application.

Microwave refers to different things in different industries. To the telecommunications industry it refers to radio relay systems operating at microwave frequencies (above 900 MHz). Within the telecommunications industry, it can mean communications over distances as short as a mile for urban applications, or as long as 45,000 miles for communications via satellite. Microwave systems can be used to communicate over bodies of water, over mountain peaks, across deserts, or across the street. And microwave can be used to transmit many forms of information – spoken words, written words, music, photographs, data pulse streams, or television programs.

Microwave systems have the advantages of large information-handling capability, high reliability, low power consumption, good protection against weather, and low maintenance costs. Disadvantages include short transmission range (from one earth antenna to another) and susceptibility to interference by objects obstructing the transmission path.

The information handling capability of a microwave system – the number of channels, data transmission rate, usable bandwidth, and similar aspects – is dependent on the performance quality required, and the stability of the transmission equipment. Performance quality is the degree of freedom from the noise and distortion which obscure signals or tend to create transmission errors.

Reliability refers primarily to freedom from equipment failure, since protection against signal fading is largely a function of system or path engineering and the use of such techniques as space diversity.

Even if the question is whether to lease channels from a common carrier or to build a new transmission system, the answer can only be found through consideration of a wide range of specifics, some common to all systems, some unique to one system alone. Systems are tailored to the required information handling capacity and the type of information to be transmitted, as well as the physical surroundings or environment in which the system is

Figure 1. Microwave networks are an integral part of the railroads' hot-box detection systems.

Figure 2. Microwave repeaters operate unattended from the tops of mountains.

expected to operate. For this reason, each system is unique in its application yet universal in its operation.

Increased Industrial Use

Microwave communications were first used commercially in 1947 to transmit voices between Boston and New York. Until recently, telephone companies were the most common commercial users of microwave for long-distance video, voice, and data transmission networks. But, more and more industries are beginning to use microwave transmission for their own communications.

A tremendous spurt to industrial usage occurred in September 1960 when the FCC (Federal Communications Commission) made microwave frequencies available to virtually any type of business or industry in the United States.

Railroads are typical among the long-time industrial users of private microwave systems. Microwave networks are used to insure the safe, smooth operation of the railroads. The status of shipments and the locations of locomotives, freight cars, and piggyback trailers is available instantly through the use of a microwave network tied to a central data processing center. An average day on the railroad might result in as many as 20,000 messages concerning moving railroad cars.

Hot-box detection systems are used to locate hot journal bearings on moving trains. These systems (see Figure 1) transmit information on the location of any hot journals to a central processing center. Mobile telephones are then used to notify train crews along the main line in order to stop trains with overheated journals. This same network can also be used to detect equipment dragging from freight cars, and to notify the train crews so that the situation can be corrected.

Microwave communications are being used for growing ACI (automatic car identification) networks that aid the railroads in computerized traffic control. Accounting for all rolling stock on one railroad is a monumental task. The task is compounded by the number of railroad companies in any one area and the free access to each others cars for handling freight. With ACI, cars are counted and identified as to owner, type and serial number. This information is automatically forwarded to a data processing center while the trains keep moving at speeds

Figure 3. Microwave systems are used for inter- and intra-island communications in Hawaii.

of up to 80 miles per hour. This system can also be used for recording cargo, destination, and direction of travel.

Since hot-box data transmission, ACI information, teletype and data transmission, and reliable voice communications are a vital part of smooth railroad operation, microwave networks are ideal for these applications.

Remote Installations

Long-haul microwave is dependable under all conditions, even when operating unattended in remote locations (see Figure 2). The reliability requirements of most microwave systems are exceedingly stringent – as close to 100% as economically possible. Systems can be provided today with propagation reliability in excess of 99.99% per hop. This kind of reliability can be expensive, but in some systems, such as pipeline control networks, the cost can be justified to get higher reliability.

Complex control networks are used in the pipeline industry to control both production and petroleum flow. Drilling and pumping operations can be remotely controlled through the use of microwave networks. Remote chemical analysis of production samples is used to control drilling. When the percentage of petroleum in a sample drops to a predetermined value, production is stopped at that well head, permanently or until further drilling locates a new source of fuel.

Along the pipeline itself status monitoring and remote supervisory control are vital to the success of the total operation. Volumetric output, flow rate, pressure, and temperature are monitored constantly. Hundreds of miles from the nearest civilization, valves are opened and closed, and pumps are automatically activated or stopped.

Although techniques and equipment vary considerably from one pipeline complex to the next, the conditions monitored and the functions performed are essentially identical – regardless of whether it is natural gas or crude oil being gathered and transported. Petroleum pipeline networks crisscross some of the most remote and rugged terrain in the world.

High, rugged mountains can actually help, rather than hinder microwave transmission, since mountain peaks permit repeater sites to be spaced further apart. Thus tower heights can

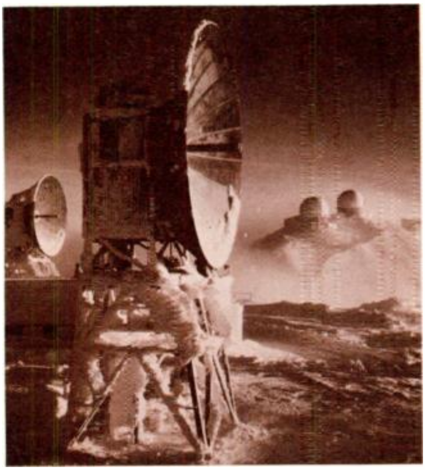


Figure 4. Ice and snow do not restrict the usefulness of this microwave defense network.

be kept to a minimum. On flat land, tower heights have to be increased to allow for earth curvature, and so that antennas can rise above man-made obstructions.

Large bodies of water do not hamper microwave transmission, either. Microwave systems are used extensively throughout the Hawaiian Islands for voice communications (see Figure 3). In fact, in some cases, communications are established by using microwave links back and forth between islands for the ultimate purpose of intra-island communications. The wire lines that had been previously used for communications within the island proved unsatisfactory since they were difficult to maintain and were sensitive to the tropical weather.

Microwave equipment is made to withstand severe weather conditions. Antennas, for example, can be heated to protect them from damage caused by ice and snow (see Figure 4). Bad weather areas, such as those subject to flooding, are particularly appropriate for microwave systems – evidence of this is offered nearly every year when microwave takes over in times of crisis to provide the only means of communicating with stricken areas.

Large bodies of water are also controlled through the use of microwave. Electric utility companies use microwave systems to remotely control the water height behind dams at hydroelectric generating stations (see Figure 5). Microwave networks are also used along transmission lines (see Figure 6) to signal a control center if the current flow becomes abnormal for reasons such as higher than normal demand, downed wires, or generator malfunction.

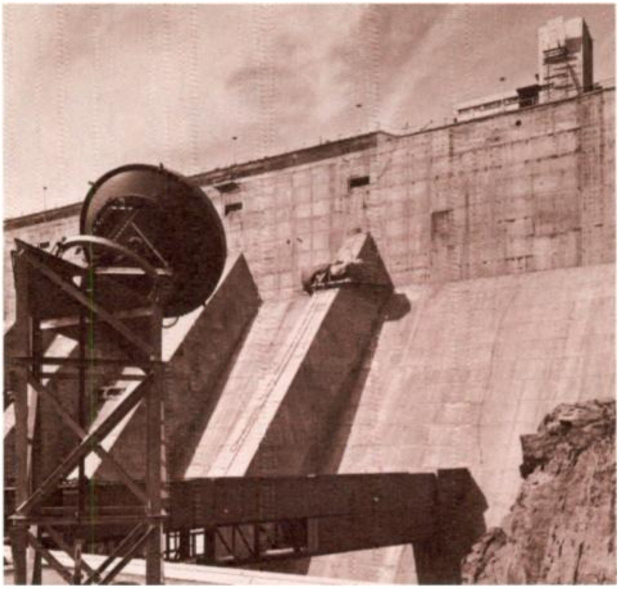
Added Advantages

Microwave communications offer certain distinct advantages over other transmission media, especially for industry or business installing its own private system. Unlike other communications systems, microwave does not require right-of-way along the total transmission path. At the same time, the installation of a microwave system still requires the acquisition of land – for terminals and repeater sites – and these areas must be provided with access roads.

The electric utilities, pipelines, and railroads own the right-of-way along their system networks. But business and private industry with scattered operations, as a rule, do not own a path of land from one office to another. Microwave, with its limited need for land acquisition, is the most promising form of private communications for business and industry.

Microwave transmission also offers a high degree of privacy – eavesdropping would have to be done right on the signal beam using electronically identical equipment. An added feature is that other systems can use the same frequency so long as they don't use the same transmission path.

Figure 5. Microwave systems are used to monitor and control generating operations at hydroelectric dams.



It is believed by many that the computer and its remote data terminals will influence human life for many decades to come. The privacy offered by microwave transmission, as well as its large information handling capacity, make microwave ideal for linking these data terminals together.

Perhaps one of the most common data networks is used by engineering groups in industry to access time sharing computer services for design work. New data networks are being established daily. Commercial banks need extensive data communications networks to keep up with the growth of credit card authorization, and for their traditional data exchanges regarding money flow. Stockbrokers and security exchanges also have to constantly keep track of money flow throughout the country and the world. Microwave systems can provide private intra- and inter-city, as well as intercountry data service for these new users.

Manufacturing plants with geographically scattered operations are finding private microwave networks useful for such things as process control, production control, inventory control, and invoicing. Many locations can be tied together by a central data processing operation.

Retail chain stores can also use private microwave networks connected to a central warehouse to make sure their shelves are properly stocked, while minimizing the need for extensive warehousing at each store. Such special purpose communications networks lead to more efficient operations and lower overhead.

Information Networks

Extensive microwave networks are used by law enforcement agencies for rapid information retrieval from centrally located files. These networks also tie together mobile base stations that are used to keep in contact with law enforcement vehicles. Instant communications are essential in law enforcement, and regional and nationwide microwave networks are being established for this purpose.

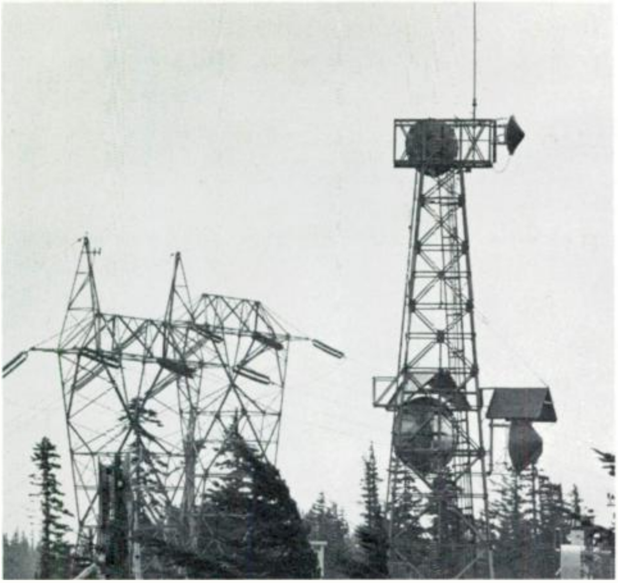


Figure 6. Electric utilities use microwave systems to monitor current flow along transmission lines.

Another form of information transmission is needed for educational purposes. Microwave installations are used to transmit university classes to industry for cooperative educational arrangements. These remote classrooms have two-way voice communications as well as video communications so that the students at both ends can participate in classroom discussions. Medical schools also use microwave installations for video transmission. Such installations permit medical students to "participate" in surgical operations without leaving their classrooms and also keep practicing doctors up to date on the latest developments in their field.

The general public can be kept informed with live radio and television news coverage of all kinds. Portable microwave systems provide wide news distribution. These systems operate from small vehicles that can be taken right to the scene as easily as taking a film crew for the same news coverage.

Microwave communications have come a long way since 1947. Today they enable people to communicate at incredible speeds anytime, anyplace, in almost any form – still and motion pictures, sophisticated computer language, heartbeats of astronauts in outer space. It speeds news copy and photos to newpapers across the country; broadcasts television programs to hundreds of cities; links military posts throughout the world; rushes diagnostic information from patients to doctors; reports the presence of unidentified aircraft to defense centers; connects bedridden students with their teachers and classrooms; and even raises and lowers drawbridges.

System operators who have sampled the benefits of microwave are adding more links to their facilities as expansion is required. And, new uses are continually being found for microwave. It is sufficient to say that microwave is widely recognized as a flexible, reliable, and economical means of providing point-to-point communications.

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ERRATUM

An error appeared on page 4, column 1, last line, of the March, 1972 Demodulator. Lenkurt Type 12 and 17 carrier systems were introduced in 1945, *not* 1954.

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